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# **Single-event Effect Report for EPC Series eGaN FETs: EPC2015, EPC2014, EPC2012**

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## **SUMMARY**

Heavy ion testing of newly available GaN FETs from EPC were tested in May of 2012 at TAM. The EPC2001, EPC2012, and EPC2014 were tested for general single-event effect response from gold and xenon ions. Overall, the devices showed radiation degradation commensurate with breakdown in isolation oxides, and similar testing by EPC and Microsemi agrees with these data. These devices were the second production generation of the device, called Gen2. The EPC2012 has a thicker epitaxial layer compared with the previous generation of the device.

## **1.0 PURPOSE**

The purpose of this testing was to characterize the newly available eGaN FET from EPC for radiation effects from heavy ions. The devices were tested for Single-Event-Effect-like Single-Event Gate Rupture (SEGR) as well as investigated for any reduction in SOA from irradiation. Dose effects from the heavy ions were also investigated.

## 2.0 TEST SAMPLES

The DUT listed in Table 2.0-1 were acquired commercially and stored under flight ESD conditions per D-57732. Since these devices were so small and the package was atypical for SEE testing, the parts had to be irradiated through the solder bumps in a dead-bug configuration. The solder varies in thickness, but it is 50  $\mu\text{m}$  at most, so ions at Texas A&M University (TAMU) could easily penetrate the entire transistor volume.

**Table 2.0-1.** List of devices that were tested.

Manufacturer	Part Number	VDS rating (max) [V]	Channel	LDC	Package
EPC	EPC2012	200	N	NA	Custom
EPC	EPC2014	40	N	NA	Custom
EPC	EPC2015	40	N	NA	Custom

### 3.0 GENERAL

All: DUTs were divided into four (4) groups of three (3) for SEGR testing, as shown in Table 3.0-1. For each irradiation, an EPC2015, EPC2014, and EPC2012 were tested.

**Table 3.0-1.** SEE/dose testing for EPC devices.

Group	Qty	Gate Bias [V]	Angle	Ion/Energy /MeV	LET [Mev.cm <sup>2</sup> /mg]	Comment
1	4	0	0	Au	~35	
2	4	0, -2.5, -5	0	Xe	~35	
3	4	0	60	Xe	~35	Only tilt angle.
4	4	0				

## 4.0 PROCEDURE/SETUP

General test procedure adhered to the “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [JPL Publication 08-10 2/08]. Parts were be serialized (if not already done), with controls marked prominently to distinguish them from test samples. Exposures were performed at ambient laboratory temperature. Since the packages from EPC were atypical, the DUTS had to be remounted in a dead-bug configuration for ion testing and testing with the ATE. Devices were verified to be functional after mounting on the test carrier, see Figure 4.0-1. The equipment used in this effort is listed in Table 4.0-1.

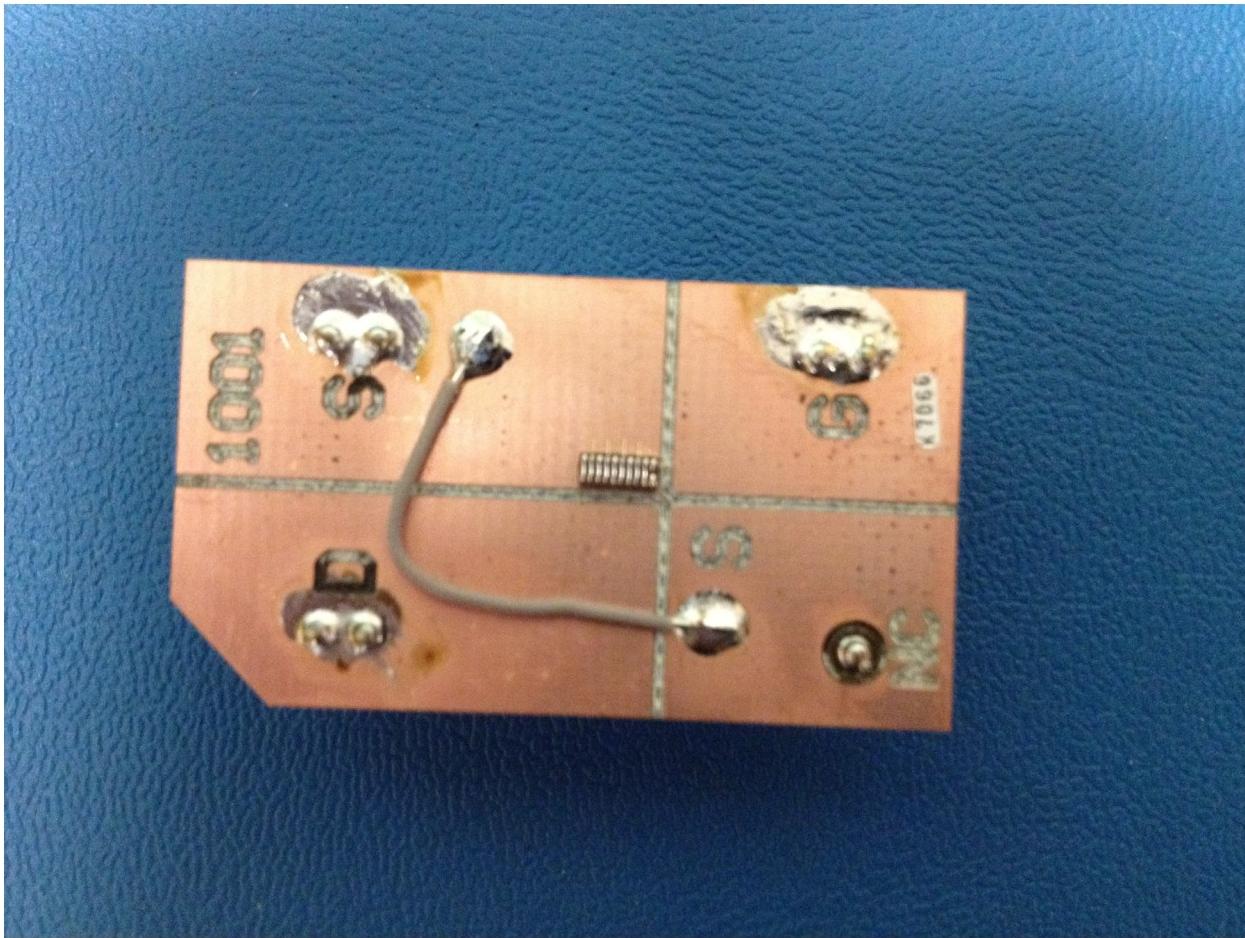


Figure 4.0-1. Dose testing carrier.

Table 4.0-1. Equipment used in this effort.

Unit	Function	Make	Calibration	JPL SN
HP4156	Parametric ATE	Agilent	20091219	TDB
HP4142	SEE ATE	Agilent	20111013	887633
Laptop	SEE control PC	Toshiba	NA	2220673

## 4.1 Electrical Tests

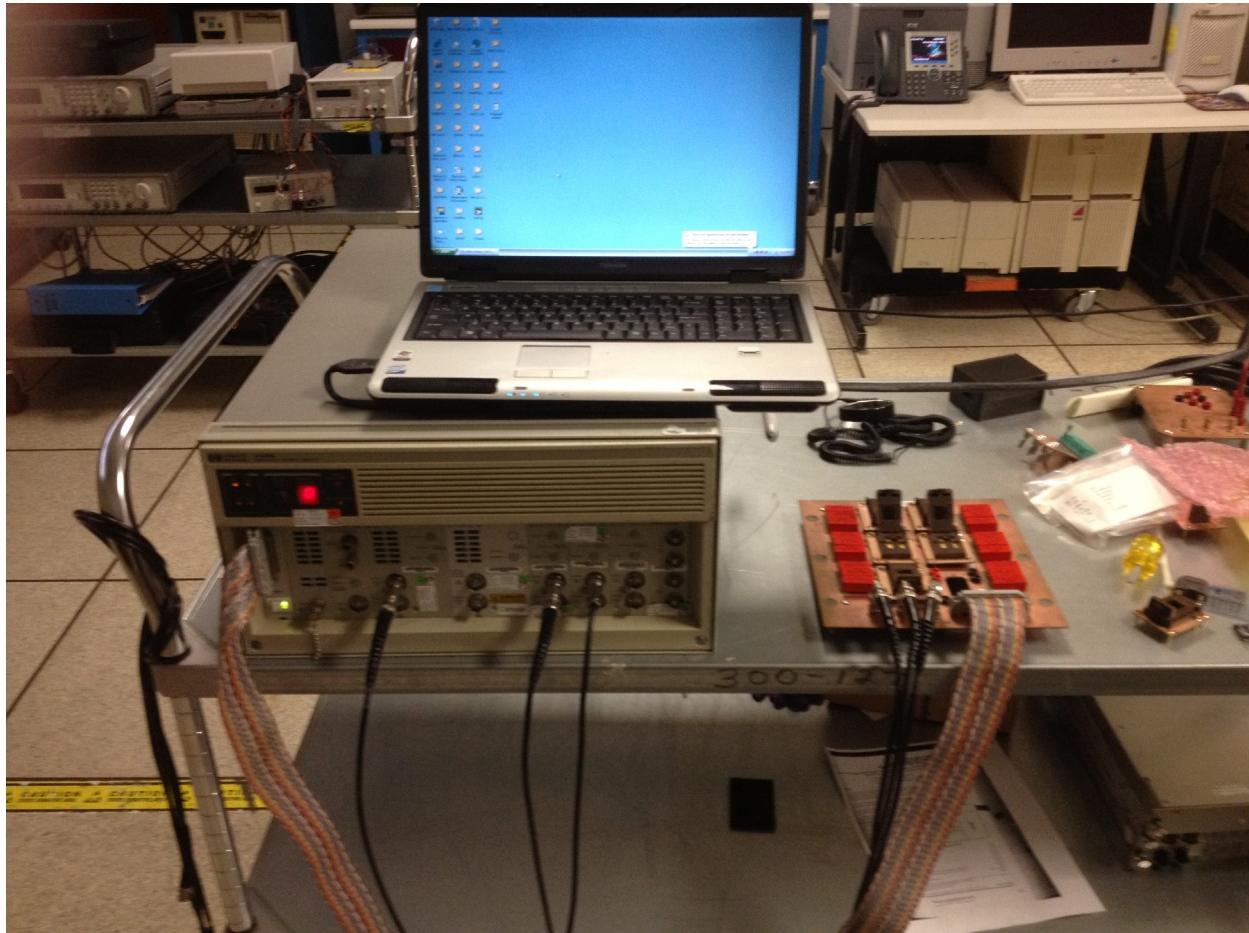
Electrical tests were performed in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [PL Publication 08-10 2/08]. All devices were verified to work by test with a HP4156. The transfer and characteristic curves of each device were acquired to a maximum current of 10 mA on any terminal of the device.

## 4.2 Failure Criteria

Failure criteria were classified in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [PL Publication 08-10 2/08]. However, any change in device parameters was noted for this exploratory effort.

## 4.3 Setup

Failure criteria were classified in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [PL Publication 08-10 2/08]. Figure 4.3-1 shows the setup used in this experiment. An HP4142 forced the voltage and read a current with three independent SMUs. The background current on the board with no DUT was recorded to be ~0.5 nA in each device location.



**Figure 4.3-1.** Setup used for SEE testing. Entire system is transported to heavy ion site.

## **5.0 RADIATION SOURCE**

The ion source was the TAMU cyclotron. The 25 MeV ion beam was used and would provide the ion ranges to penetrate the solder to reach the sensitive volume.

## **6.0 BIAS CONDITION/FIXTURES**

Bias condition during the biased irradiations were in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [PL Publication 08-10 2/08]. Unbiased parts were exposed in a manner that protects them against ESD.

## 7.0 RESULTS

The eighteen devices that were tested have the results listed in Table 7.0-1. The EPC2000 series showed dose damage with the following trends:

1. At normal incidence, the higher LET gold ion did more damage (destructive SEE at low voltage) than xenon. This was expected.
2. Devices with lower voltage rating were less susceptible to SEE damage. This was also expected.
3. Devices irradiated at 60 degrees showed little degradation.
4. Devices irradiated at 60 degrees showed catastrophic SEE with no dose damage precursors.
5. Negative gate voltage has no effect on the SEE response.

The dose degradation affected the following measured parameters: IDSS, Vth, and gm. The results are presented in the following figures.

- Figure 7.0-1 presents part K7347, EPC2014.
- Figure 7.0-2 presents part K7325, EPC2014.
- Figure 7.0-3 presents part K7328, EPC2014.
- Figure 7.0-4 presents part K7320, EPC2015.
- Figure 7.0-5 presents part K7303, EPC2015.
- Figure 7.0-6 presents part K7305, EPC2015.
- Figures 7.0-7 and 7.0-8 present part K7348, EPC2012.
- Figures 7.0-9 and 7.0-10 present part K7350, EPC2012.
- Figures 7.0-11 and 7.0-12 present part K7352, EPC2012.
- Figures 7.0-13 and 7.0-14 present part K7353, EPC2012.
- Figures 7.0-15 and 7.0-16 present part K7354, EPC2012.
- Figures 7.0-17 and 7.0-18 present part K7359, EPC2012.
- Figures 7.0-19 and 7.0-20 present part K7361, EPC2012.
- Figures 7.0-21 and 7.0-22 present part K7364, EPC2012.
- Figures 7.0-23 and 7.0-24 present part K7365, EPC2012.
- Figures 7.0-25 and 7.0-26 present part K7371, EPC2012.
- Figures 7.0-27 and 7.0-28 present part K7012, EPC1012.

**Table 7.0-1.** Top level results of the initial EPC testing.

PN	Part	Vdd (rated) [V]	VGS [V]	Ion	Energy [MeV]	Angle Deg	LET [MeV.mg/cm <sup>2</sup> ]	Range [μm]	VDSpass [V]	VDSsee [V]	Vave [V]
K7347	EPC2014	40	0	Au	2365	0	84.6	124.1	40	40	40
K7325	EPC2014	40	0	Xe	1583	0	50.8	125.7	40	40	40
K7328	EPC2014	40	0	Xe	1583	0	50.8	125.7	40	40	40
K7320	EPC2015	40	0	Au	2365	0	84.6	124.1	40	40	40
K7305	EPC2015	40	0	Xe	1583	0	50.8	125.7	40	40	40
K7303	EPC2015	40	0	Xe	1583	0	50.8	125.7	40	40	40
K7012	EPC1012	200	0	Xe	1583	60	101.5	62.9	80	100	90
K7354	EPC2012	200	0	Au	2365	0	84.6	124.1	20	40	30
K7352	EPC2012	200	0	Xe	1583	0	50.8	125.7	80	100	90
K7350	EPC2012	200	0	Xe	1583	0	50.8	125.7	60	80	70
K7348	EPC2012	200	0	Xe	1583	0	50.8	125.7	60	80	70
K7353	EPC2012	200	-2.5	Xe	1583	0	50.8	125.7	40	60	50
K7365	EPC2012	200	-2.5	Xe	1583	0	50.8	125.7	80	100	90
K7371	EPC2012	200	-5	Xe	1583	0	50.8	125.7	80	120	100
K7359	EPC2012	200	0	Xe	1583	60	101.5	62.9	200	200	200
K7364	EPC2012	200	0	Xe	1583	0	50.8	125.7	60	80	70
K7361	EPC2012	200	0	Xe	1583	60	101.5	62.9	120	140	130

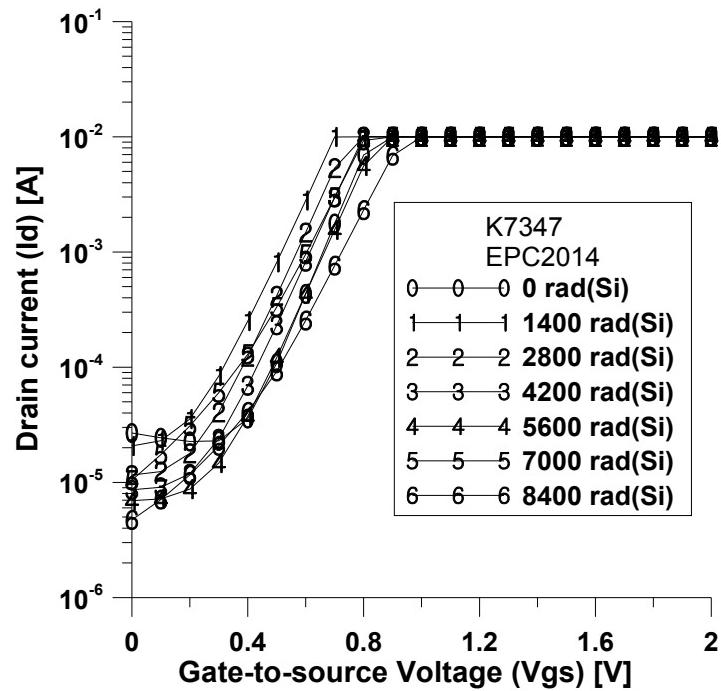


Figure 7.0-1. Effect of heavy ion radiation on the transfer curve of part K7347. Drain voltage was 10 V.  
No SEE was seen to  $V_{ds}=40$  V and  $V_{gs}=-5$  V.

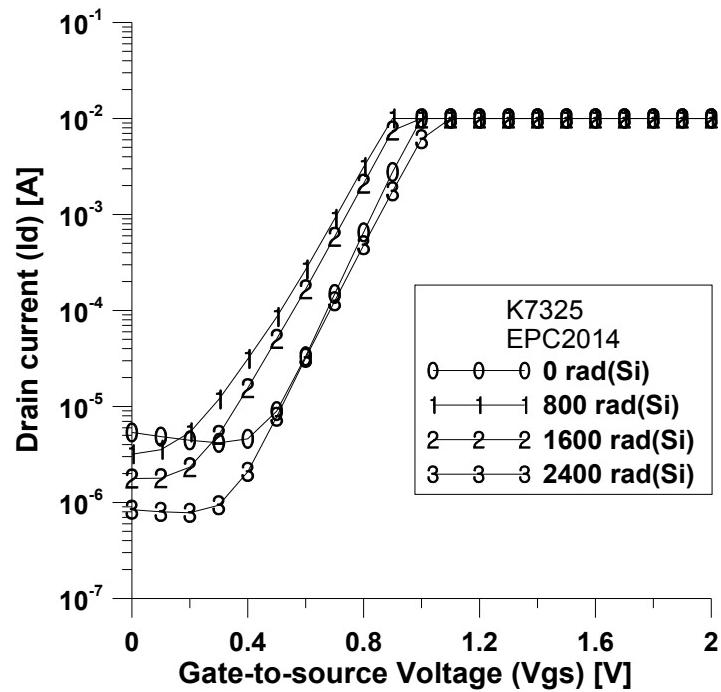
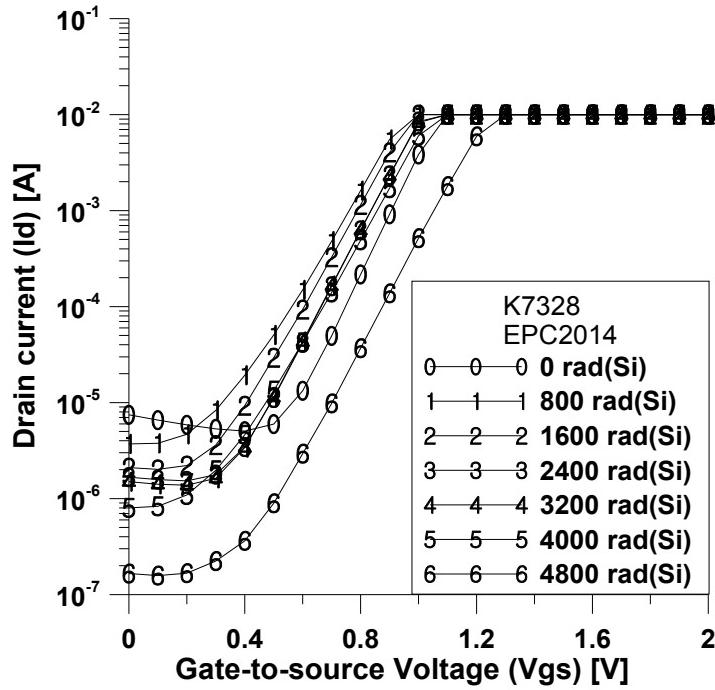
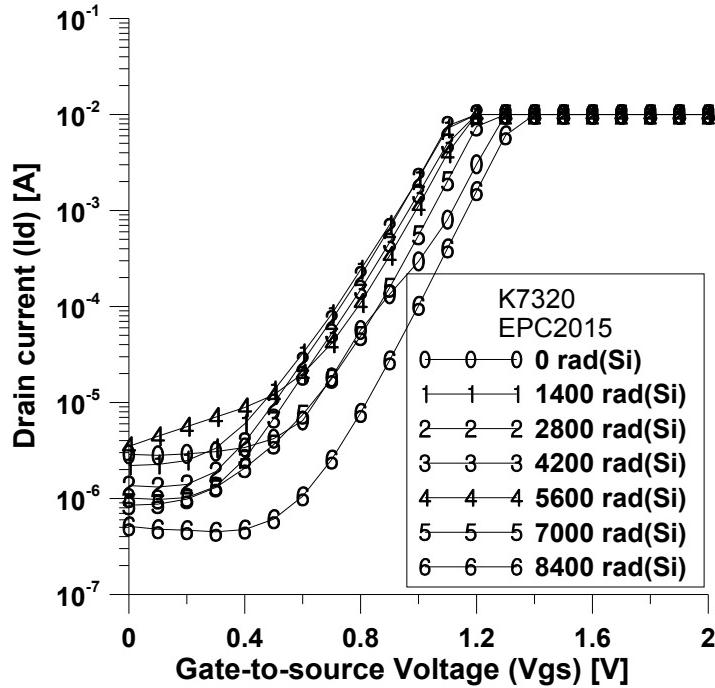


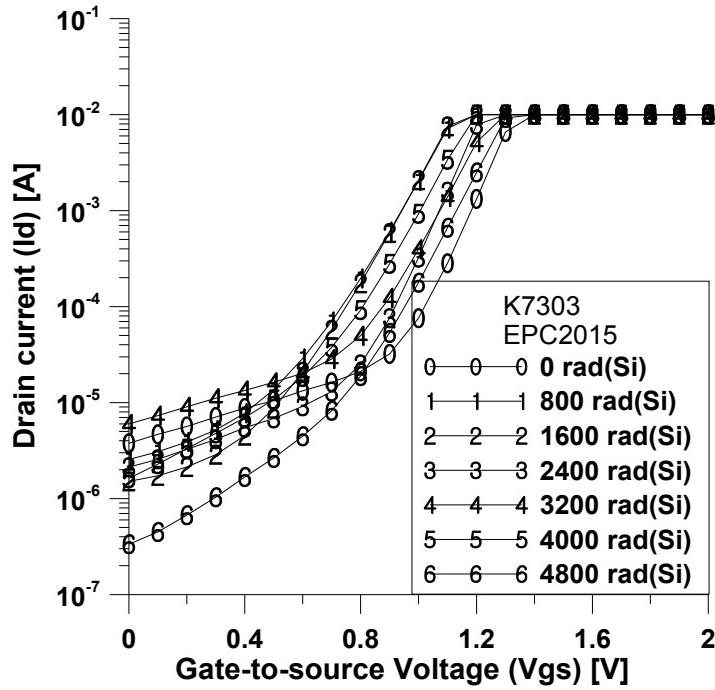
Figure 7.0-2. Effect of heavy ion radiation on the transfer curve K7325. Drain voltage was 10 V.  
No SEE was seen to  $V_{ds}=40$  V and  $V_{gs}=-5$  V.



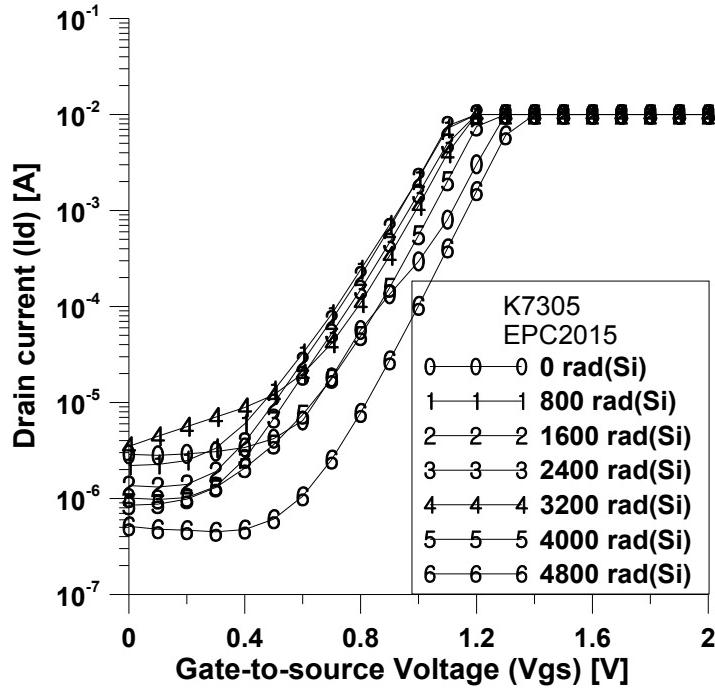
**Figure 7.0-3.** Effect of heavy ion radiation on the transfer curve K7328. Drain voltage was 10 V.  
No SEE was seen to  $V_{ds}=40$  V and  $V_{gs}=-5$  V.



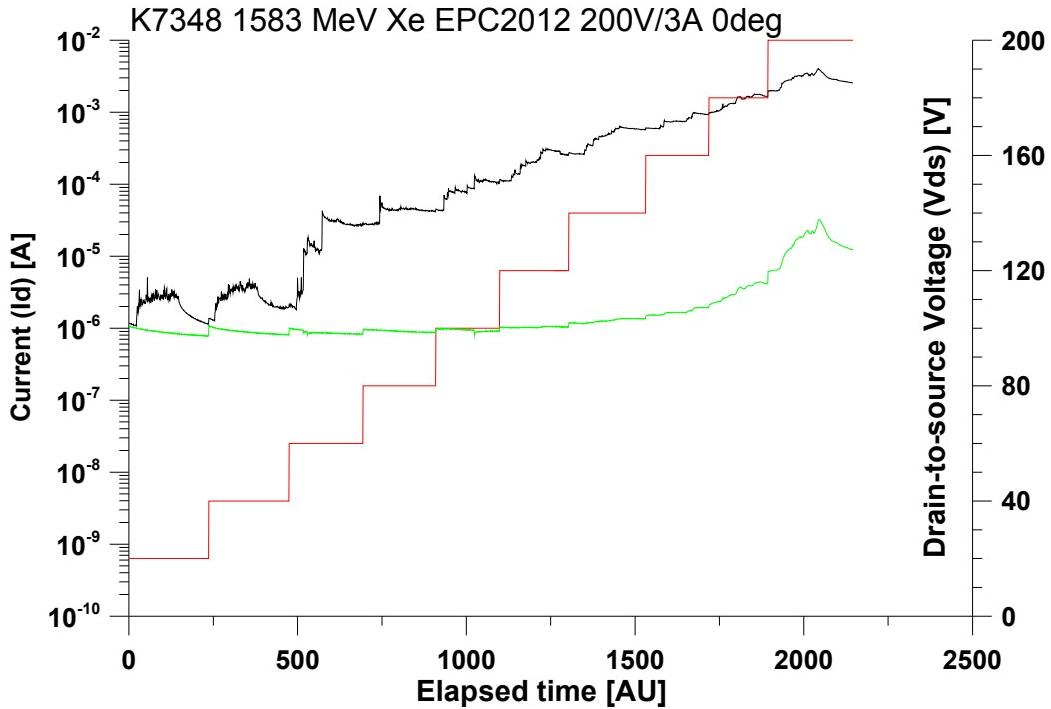
**Figure 7.0-4.** Effect of heavy ion radiation on the transfer curve K7320. Drain voltage was 10 V.  
No SEE was seen to  $V_{ds}=40$  V and  $V_{gs}=-5$  V.



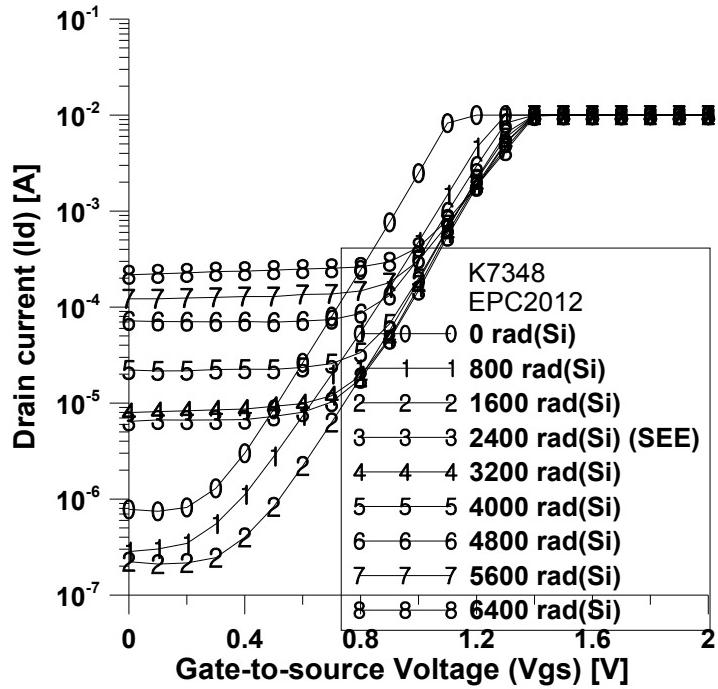
**Figure 7.0-5.** Effect of heavy ion radiation on the transfer curve K7303. Drain voltage was 10 V.  
No SEE was seen to  $V_{ds}=40$  V and  $V_{gs}=-5$  V.



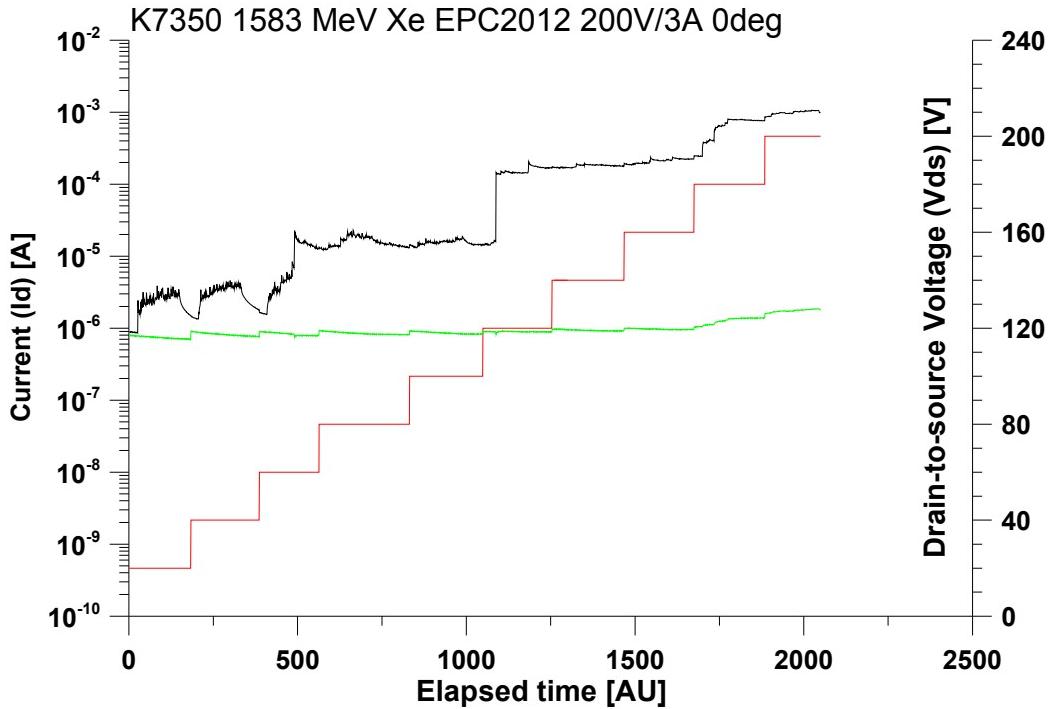
**Figure 7.0-6.** Effect of heavy ion radiation on the transfer curve K7305. Drain voltage was 10 V. Drain voltage was 10 V.  
No SEE was seen to  $V_{ds}=40$  V and  $V_{gs}=-5$  V.



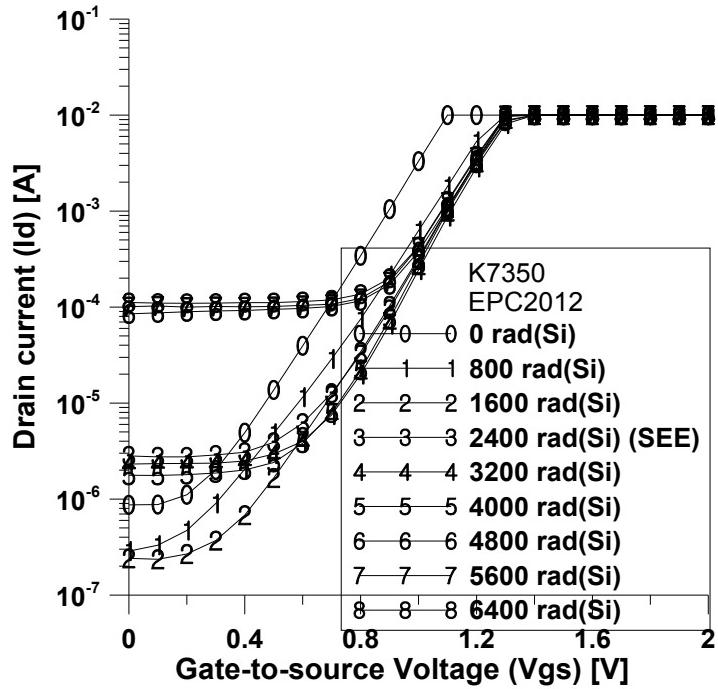
**Figure 7.0-7.** Heavy ion response of the EPC2012 200 V/3 A. Ion flux was  $3E4 \text{ cm}^{-2}\text{-s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current. The SEE occurred at  $V_{ds}=60 \text{ V}$  and  $V_{gs}=0 \text{ V}$ .



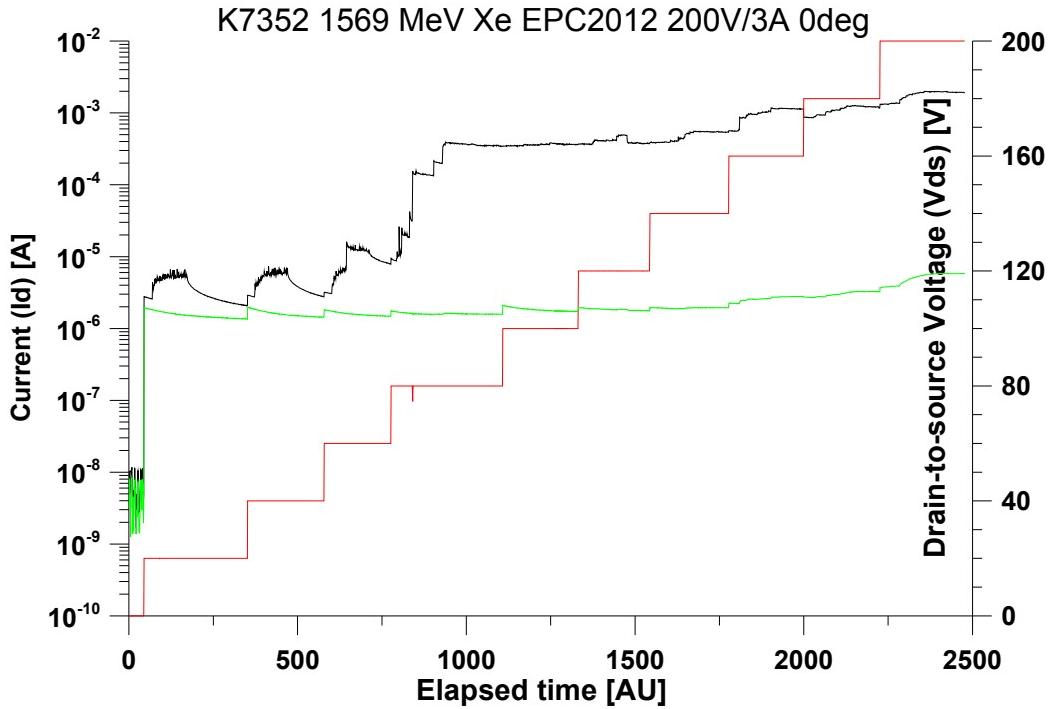
**Figure 7.0-8.** Effect of heavy ion radiation on the transfer curve K7348. Drain voltage was 10 V. Note the increase in drain leakage after the SEE.



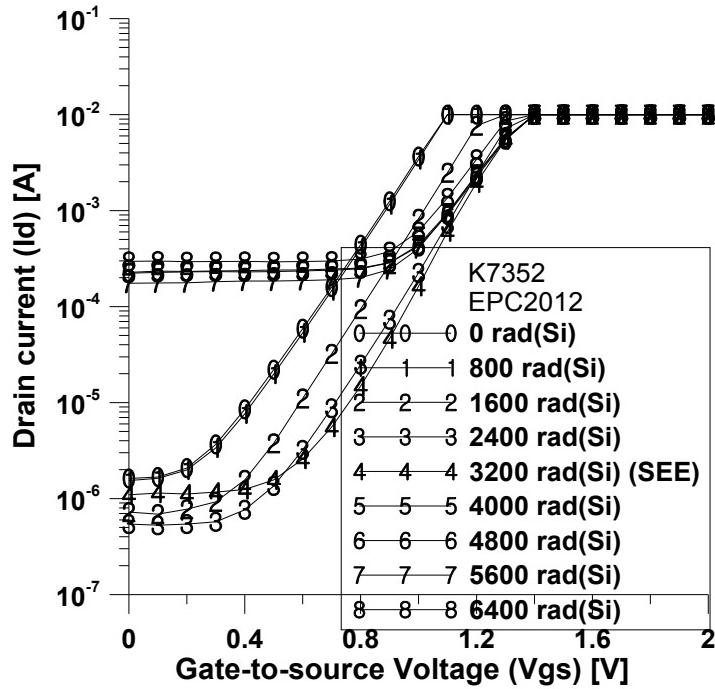
**Figure 7.0-9.** Heavy ion response of the EPC2012 200 V/3 A. Ion flux was  $3E4 \text{ cm}^{-2}\text{-s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current. The SEE occurred at  $V_{ds}=60 \text{ V}$  and  $V_{gs}=0 \text{ V}$ .



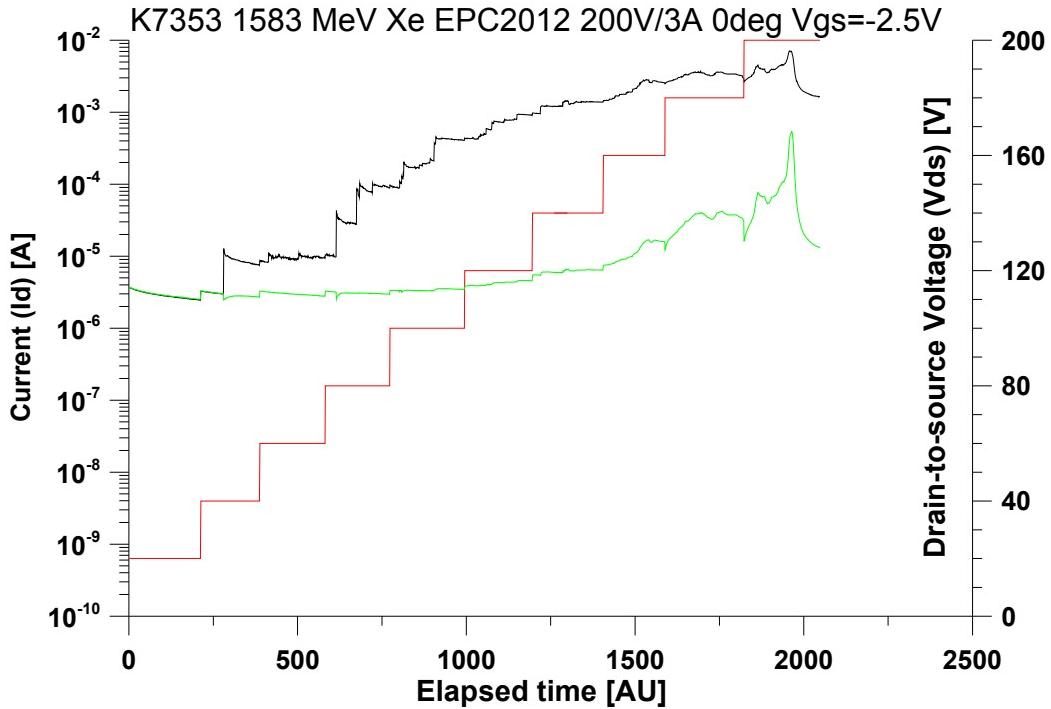
**Figure 7.0-10.** Effect of heavy ion radiation on the transfer curve K7350. Drain voltage was 10 V. Note the increase in drain leakage after the SEE.



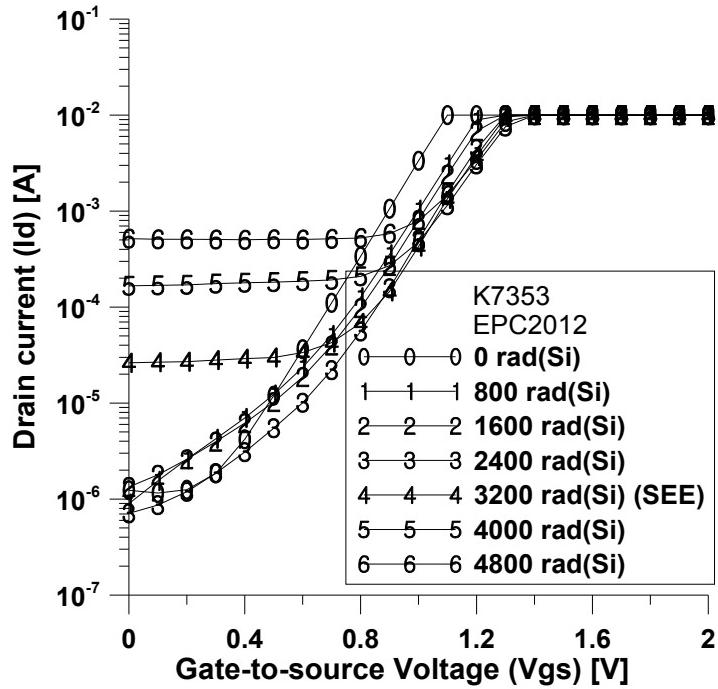
**Figure 7.0-11.** Heavy ion response of the EPC2012 200 V/3 A. Ion flux was  $3E4 \text{ cm}^{-2}\text{-s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current. The SEE occurred at  $V_{ds}=60 \text{ V}$  and  $V_{gs}=0 \text{ V}$ .



**Figure 7.0-12.** Effect of heavy ion radiation on the transfer curve K7352. Drain voltage was 10 V. Note the increase in drain leakage after the SEE.



**Figure 7.0-13.** Heavy ion response of the EPC2014 40 V/10 A 60 deg. Ion flux was  $3E4 \text{ cm}^{-2}\text{s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current. The SEE occurred at  $V_{ds}=40 \text{ V}$  and  $V_{gs}=0 \text{ V}$ .



**Figure 7.0-14.** Effect of heavy ion radiation on the transfer curve K7353. Drain voltage was 10 V.

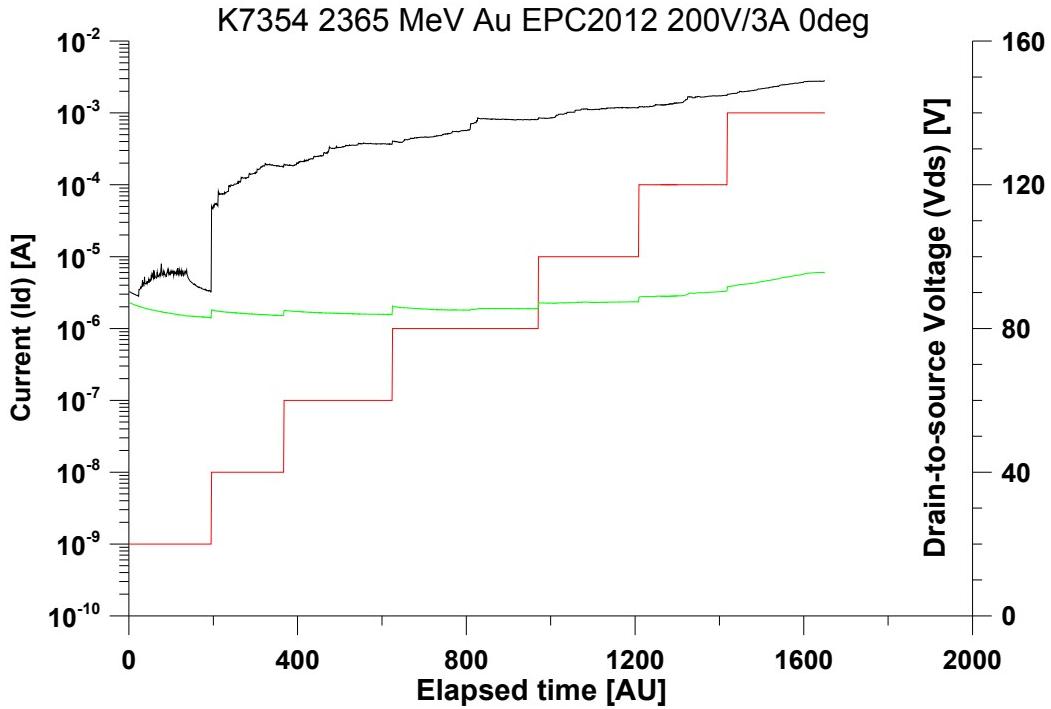


Figure 7.0-15. Heavy ion response of the EPC2012 200 V/3 A. Ion flux was  $3E4 \text{ cm}^{-2}\text{-s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

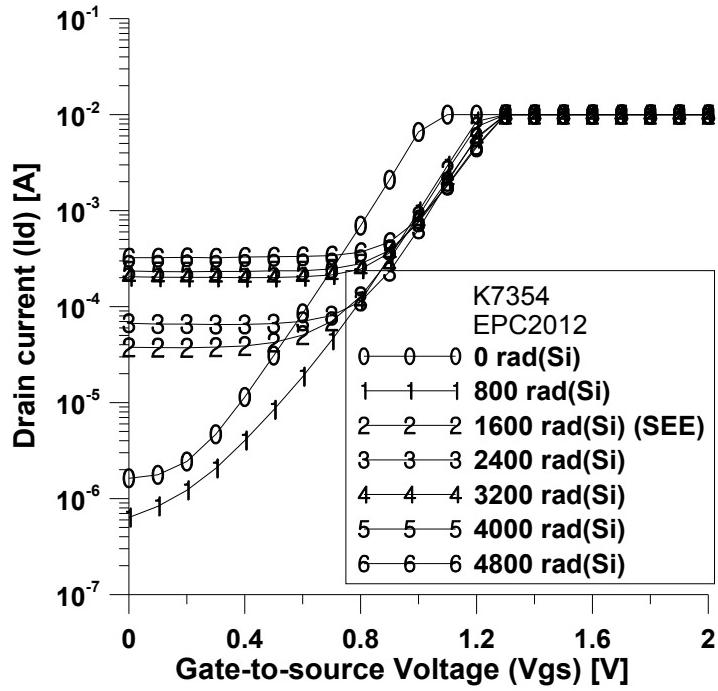


Figure 7.0-16. Effect of heavy ion radiation on the transfer curve K7354. Drain voltage was 10 V.

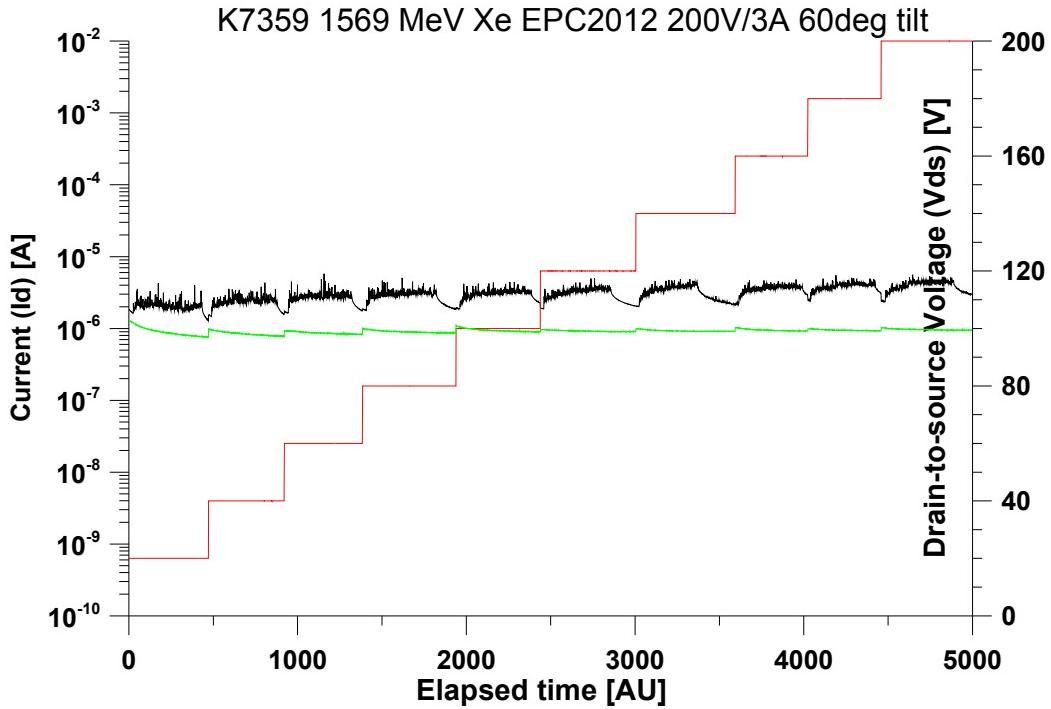


Figure 7.0-17. Heavy ion response of the EPC2012 200 V/3 A 60 deg. Ion flux was  $3E4 \text{ cm}^{-2}\text{s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

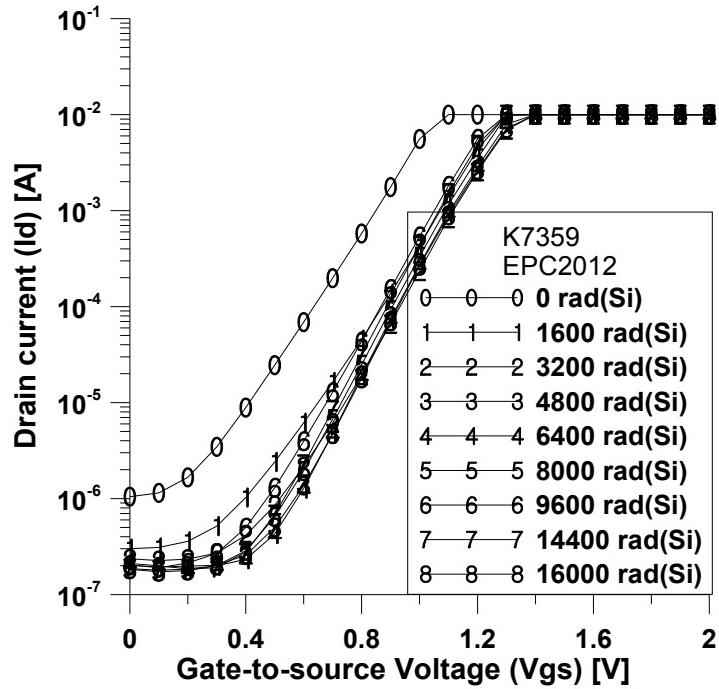


Figure 7.0-18. Effect of heavy ion radiation on the transfer curve K7359. Drain voltage was 10 V.

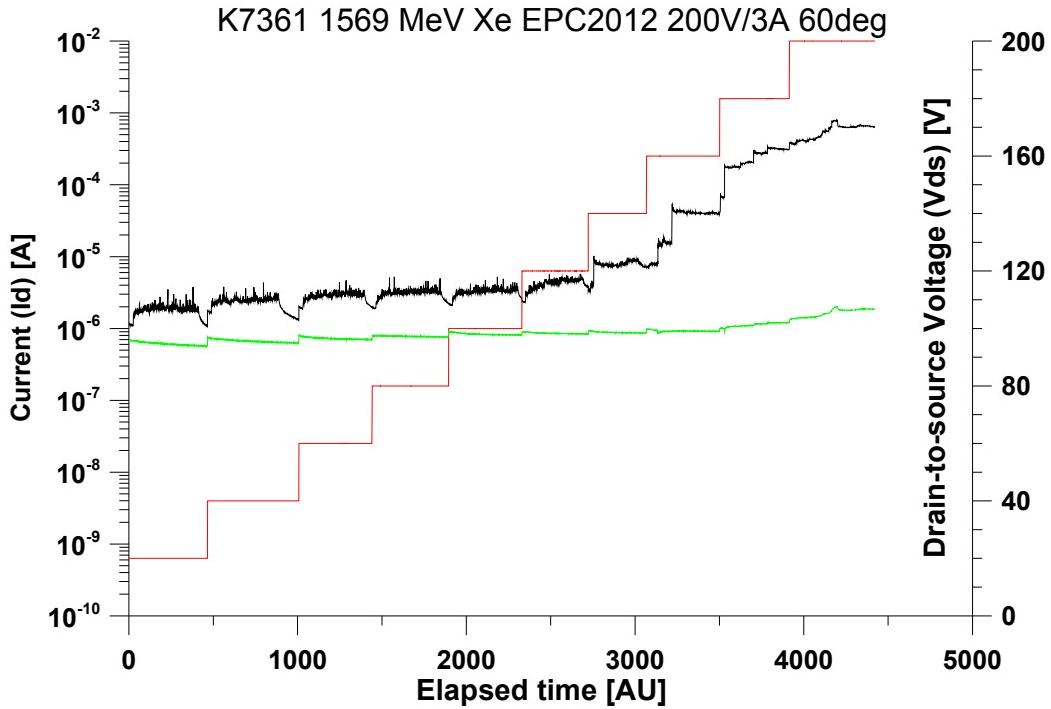


Figure 7.0-19. Heavy ion response of the EPC2012 200 V/3 A 60 deg. Ion flux was  $3E4 \text{ cm}^{-2}\text{s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

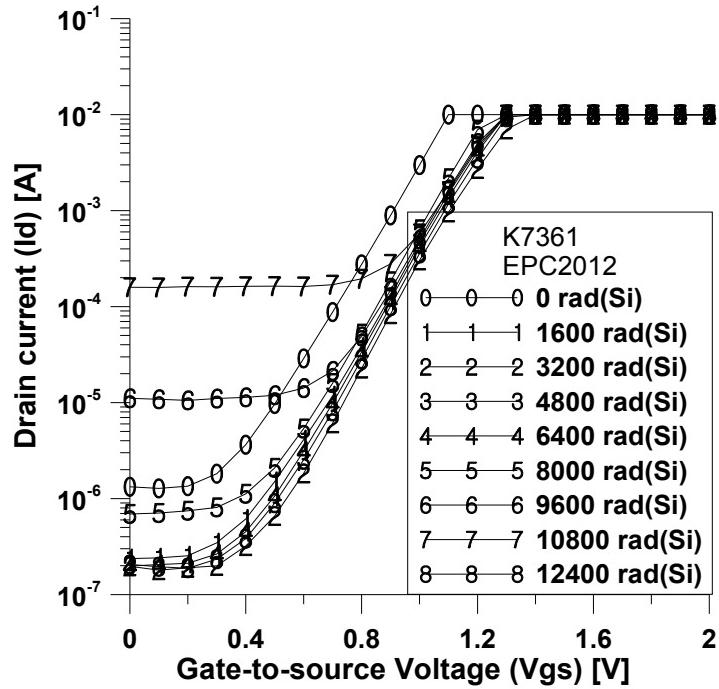
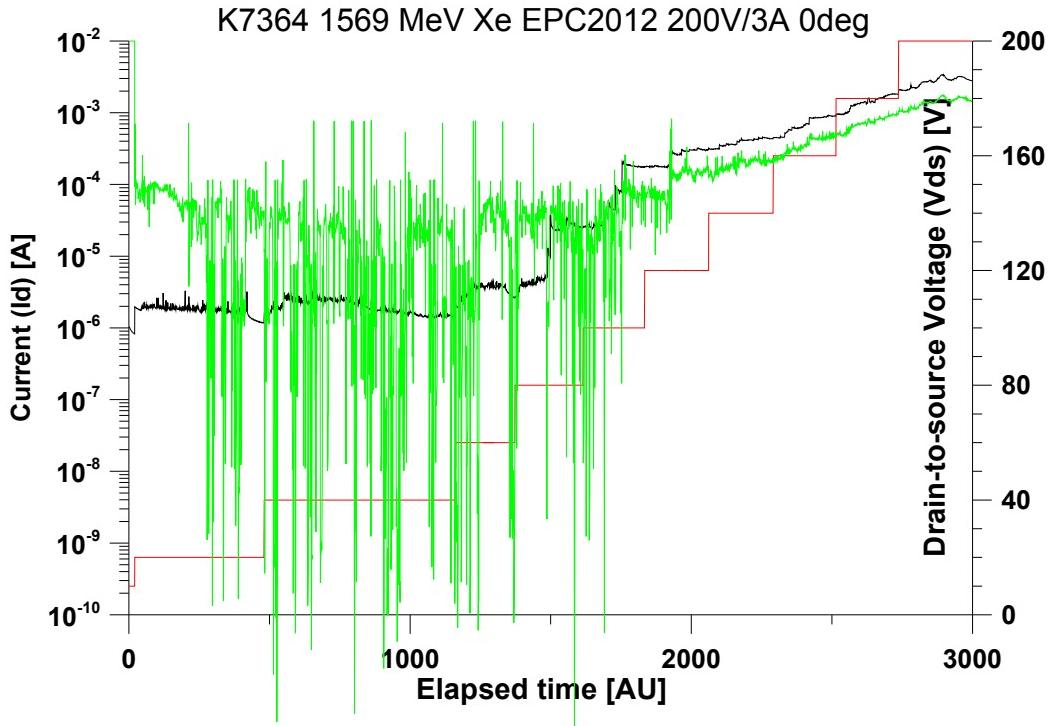
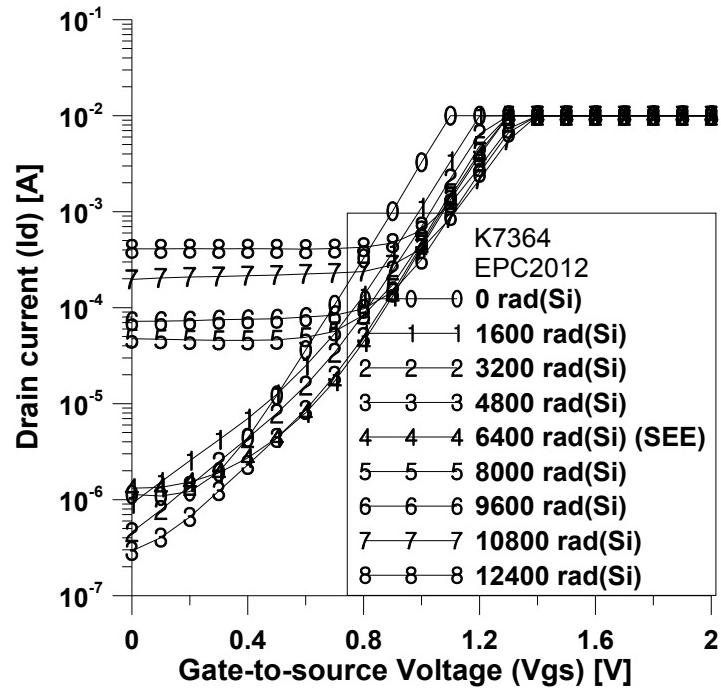


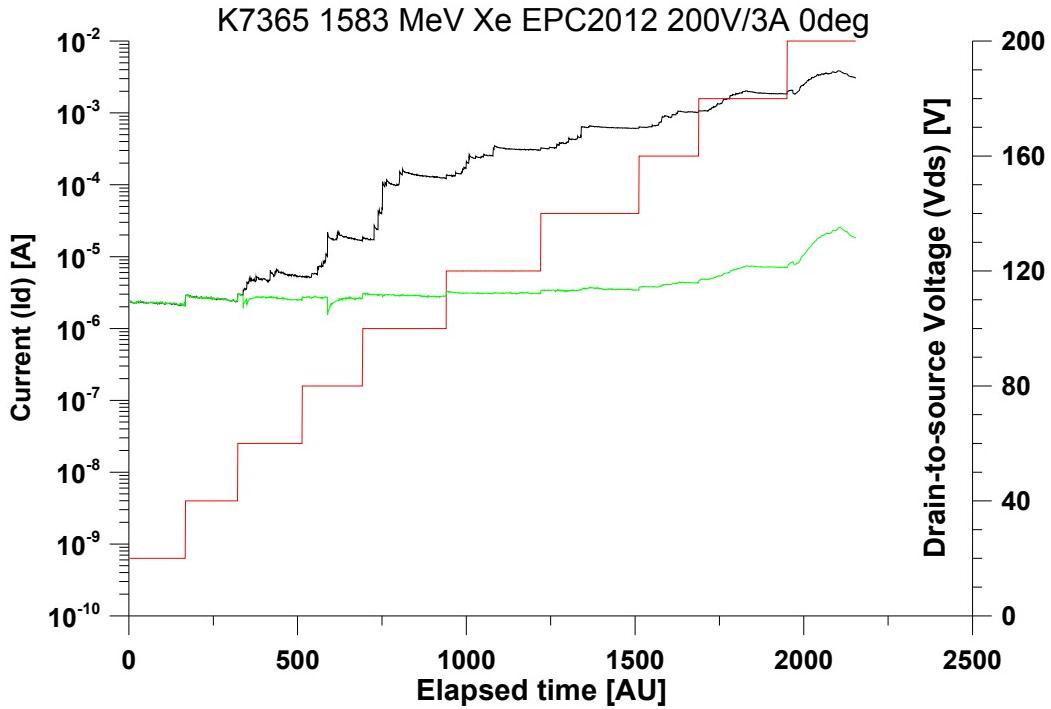
Figure 7.0-20. Effect of heavy ion radiation on the transfer curve K7361. Drain voltage was 10 V.



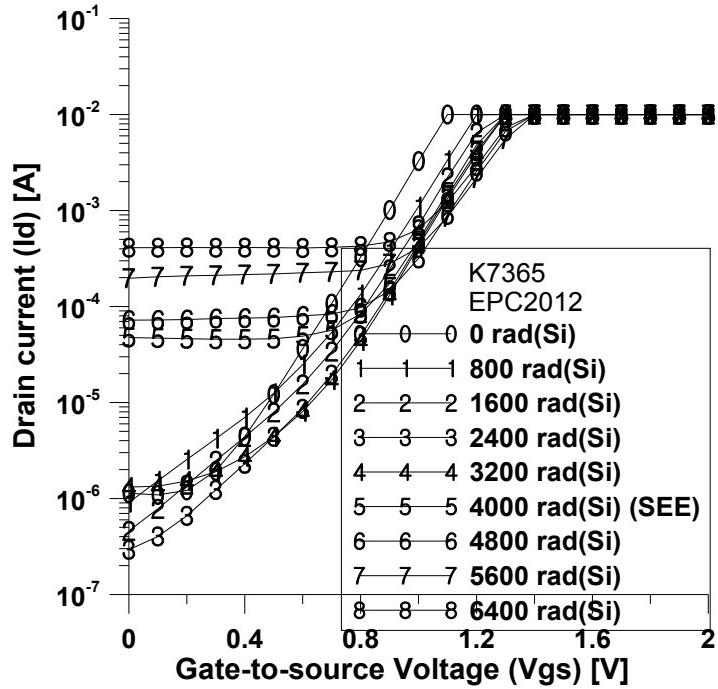
**Figure 7.0-21.** Heavy ion response of the EPC2012 100 V/25 A 0 deg. Ion flux was  $3\text{E}4 \text{ cm}^{-2}\text{-s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current. Current noise occurs is seen in some devices when near the voltage threshold.



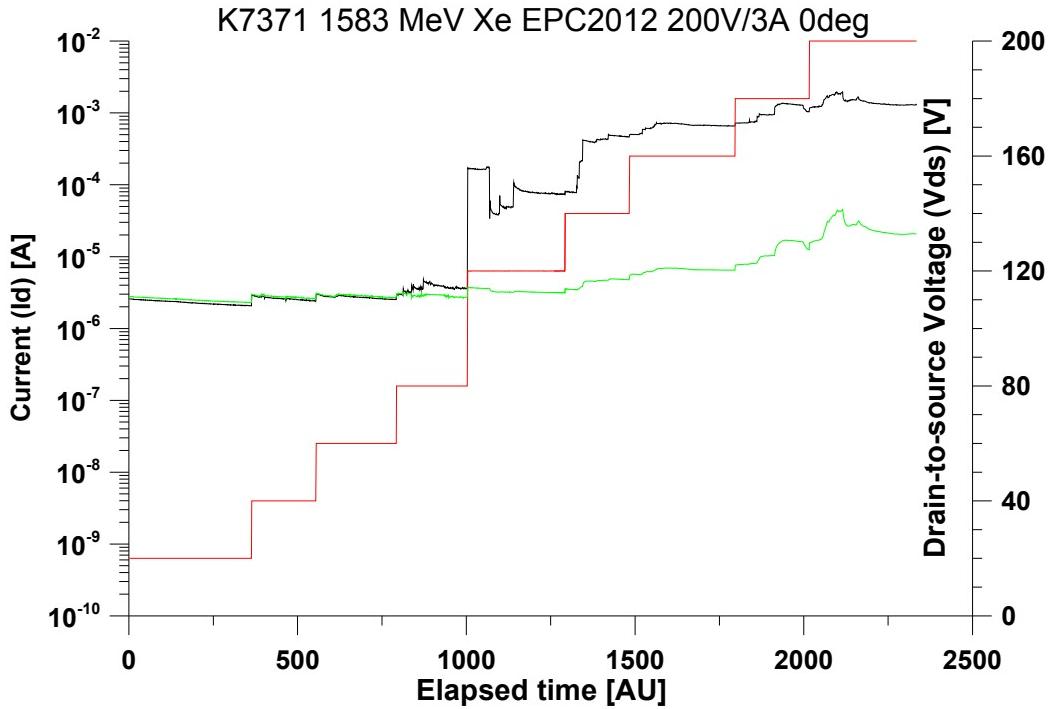
**Figure 7.0-22.** Effect of heavy ion radiation on the transfer curve K7364. Drain voltage was 10 V.



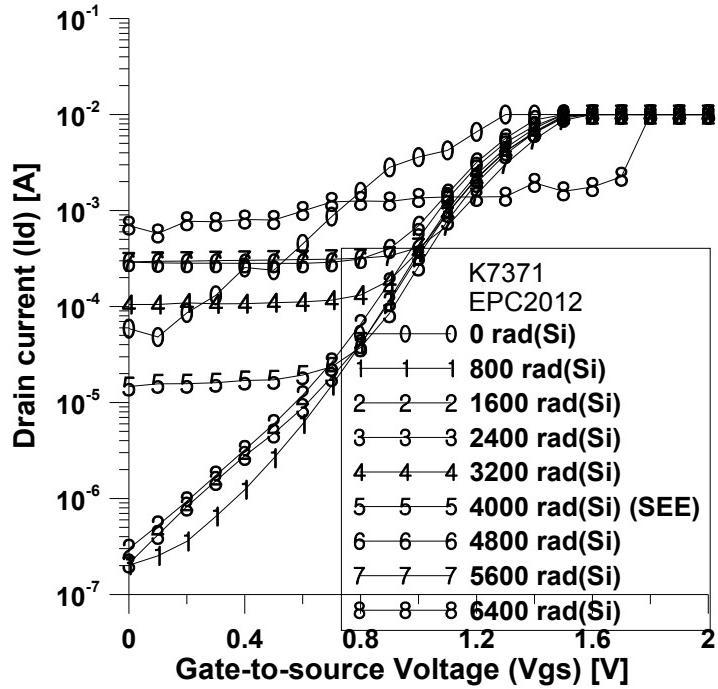
**Figure 7.0-23.** Heavy ion response of the EPC2012 100 V/25 A 0 deg. Ion flux was  $3E4 \text{ cm}^{-2}\text{s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current. Drain-to-source voltage =  $-2.5 \text{ V}$ .



**Figure 7.0-24.** Effect of heavy ion radiation on the transfer curve K7365. Drain voltage was 10 V.



**Figure 7.0-25.** Heavy ion response of the EPC2012 100 V/25 A 0 deg. Ion flux was  $3E4 \text{ cm}^{-2}\text{s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current. Drain-to-source voltage =  $-2.5 \text{ V}$ .



**Figure 7.0-26.** Effect of heavy ion radiation on the transfer curve K7371. Drain voltage was  $10 \text{ V}$ .

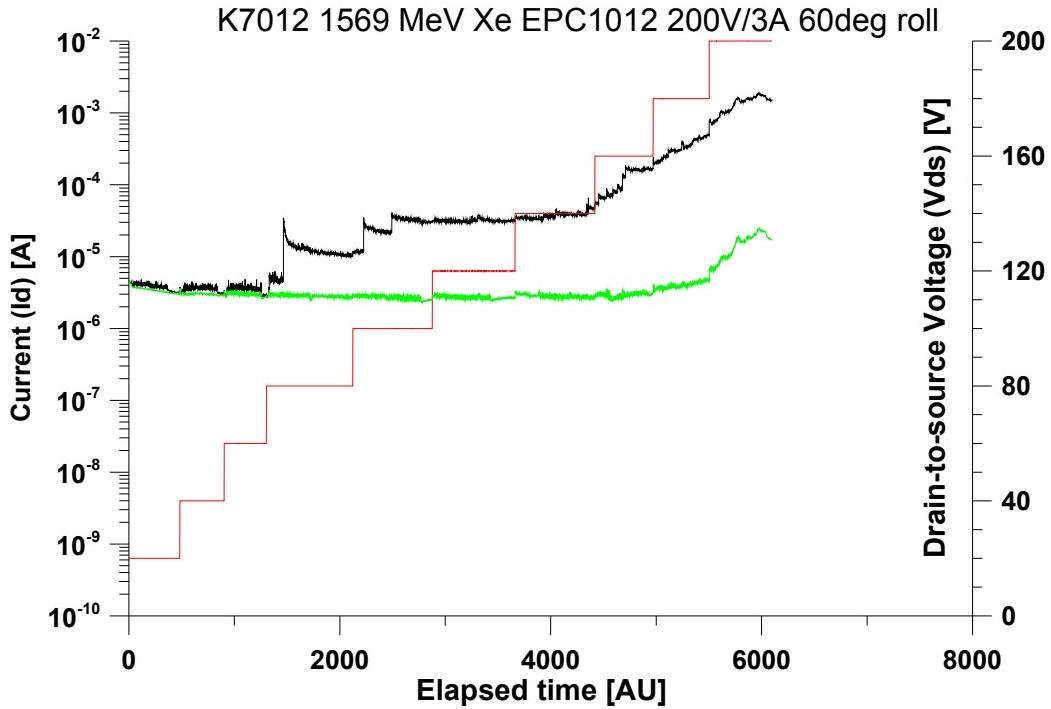


Figure 7.0-27. Heavy ion response of the EPC1012 100 V/25 A 60 deg. Ion flux was  $3E4 \text{ cm}^{-2}\text{-s}^{-1}$ . Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current. .

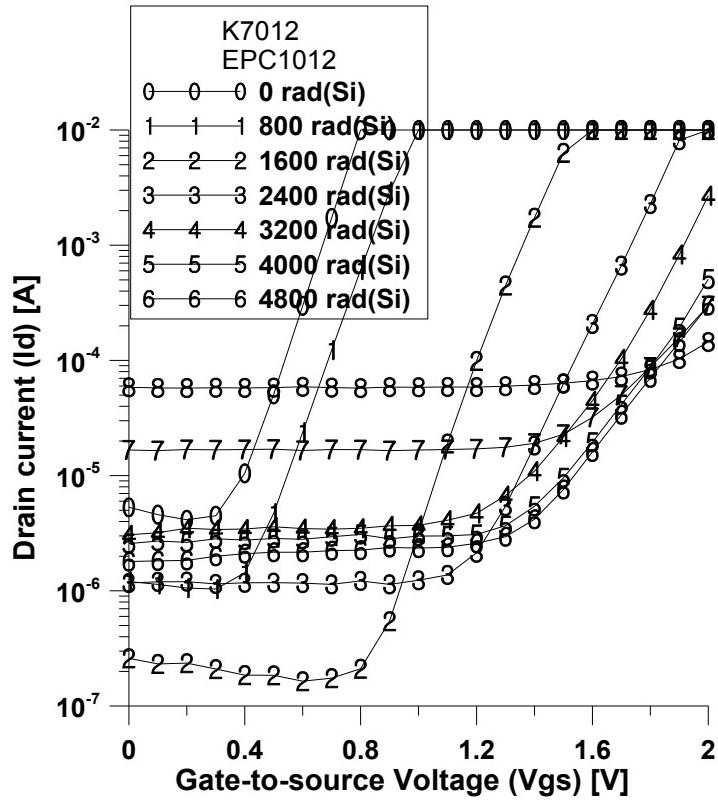


Figure 7.0-28. Effect of heavy ion radiation on the transfer curve K7012. Drain voltage was 10 V.

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